



Detailed Design

“The intent of the detailed design phase of the project is to develop a system of drawings that completely describe a proven and tested design so that it can be manufactured”¹. “Drawings”, in this context, can be interpreted as schematics, block diagrams, assembly drawings, parts lists, printed circuit board layouts, parts layouts, program code, wiring diagrams or instructions, test plans and specifications or any other documentation needed to completely build (manufacture) the design in question.

This phase involves a lot of detailed work, but also a lot of effort in documentations and testing. In fact, Salt and Rothery² suggest (p 105) a reasonable allocation of the designers time in this phase would be to spend approximately one third on their efforts on actual design work (the synthesis, analysis cycle), one third on testing (both to verify that the design meets specifications and to establish benchmark data for assembly testing and maintenance / troubleshooting), and one third on documentation (drawings, schematics, acceptance test specifications etc.).

Documenting for manufacturing needs can be challenging, especially for one with limited experience. Ertas and Jones (p 24, 25) offer a list of considerations to help make a design “manufacture friendly”. The following list is adapted from theirs and modified for the field of electrical engineering:

1. *Minimize the number of parts.* This is easier to do as more complex integrated circuits become available and as field programmable devices become larger, less expensive and thus more popular. The result can be reduced size, power consumption, cost and improved reliability.
2. *Use modular design techniques.* Grouping technology or similar functions in one sub-assembly also offers advantages. E.g., grouping electronic components in one module and electro-mechanical in another might allow common automated assembly lines to produce one module quickly and efficiently, while all hand-assembled components could be done on another line, also realizing a more efficient manufacture. Also, breaking down large, complex designs into individual modules may also be advantageous. Extremely large boards are difficult to handle and assemble, while smaller ones can be automated easily. There are also advantages in maintenance and repair (e.g. just have to replace one module).
3. *Use standard parts.* Bulk purchase of a minimal number of parts usually means a better purchase price and lower warehousing costs. An example would be to implement all required logic using one type of I.C.

¹ Ertas, A., and Jones, J. C., 1993, *The Engineering Design Process.*, John Wiley and Sons

² Salt, J. Eric, and Rothery, Robert, 2002, *Design for Electrical and Computer Engineers*, John Wiley and Sons

4. *Use necessary components for multiple purposes where possible.* An example might be the chassis holding a circuit board. It can also act as a ground plane, heat sink or shield.
5. *Take advantage of available sub-assemblies or components.* A common example is an external power supply. Readily available modules reduce the need for standards approvals, reduce costs and save time. Other pre-packaged modules may also be available to simplify your design and improve reliability.
6. *Minimize connectors and wiring.* Connectors and flexible wiring are expensive to buy and assemble and are often the cause of reliability problems over the long term. Where they must be used, consider standard, common parts (point 3) as opposed to custom designs.
7. *Minimize required adjustments and settings.* Adjusting potentiometers or variable capacitors is time consuming and expensive during manufacture, not to mention the reliability problems of this type of “moving part”, particularly in adverse environments. Try to design so that standard value, fixed components are all that is required, or that adjustments are made automatically either electronically or in software.
8. *Consider ‘tolerance build-up’.* Any good design should consider the effect of the concatenation of components at the “worst case” limits of their specified tolerance. Make sure that the design will function with “marginal” components, or at least develop a way to detect marginal units before they leave the factory.

More on Creative Design and Innovation

Generating more ideas:

“Brainstorming” (or “green lighting”) was previously discussed. Kemper³ includes another technique for inspiring creativity. Called the “forced relationship techniques” (p 231), it is attributed to, and reprinted with permission from Eugene K. Von Fange⁴. This technique is similar in some respects to some of the suggestions made by Salt and Rothery² for generating alternative solutions. It involves taking an existing invention or solution and attempting to come up with innovative alternative solutions or uses by cycling through a checklist of questions designed to force thinking in a new direction. The list is (verbatim):

1. Put to other uses?
2. Adapt? Copy good ideas from other objects?
3. Modify? Change color, sound, odor, shape?
4. Magnify? Thicker, heavier, multiply components. Ecaggerate?

³ Kemper, J. D., *Introduction to the Engineering Profession*, 1984, Holt, Rinehart and Winston

⁴ Von Fange, Eugene K., 1959, *Professional Creativity*, Prentice-Hall, Inc., Englewood Cliffs, N. J.

5. Minify? Subtract, condense, lighten, streamline?
6. Substitute? Other ingredients, processes, or approaches?
7. Rearrange? Interchange, change sequence, transpose cause and effect?
8. Reverse? Backward, upside down, transpose positive and negative?
9. Combine? Blend, or produce assortment?

Note that this list could be shortened or modified, depending on the objectives of the exercise.

Creative Traits:

Kemper cites another interesting observation on creativity which resulted from psychological studies attempting to identify creative traits⁵. Kemper offers:

"Briefly, as compiled from studies by Roe, McClelland, Barron, Saunders MacCurdy, Knapp, and Cattell, the typical traits of the productive *scientist* are:

1. Self-sufficiency and capacity for self-direction,
2. Preference for mental challenges; detached attitude in social matters,
3. A big ego,
4. Preference for exactness,
5. Preference for isolation, as a defense mechanism,
6. High personal dominance, but a dislike for controversy,
7. High self-control, even overcontrol; little impulsiveness,
8. A liking for abstractness,
9. Independent thinking; rejection of group pressures,
10. Superior intelligence,
11. An early interest in intellectual matters,
12. Comprehensiveness and elegance in explanation,
13. An enjoyment in pitting oneself against uncertain circumstances."

While engineers (at least the stereo-typical type) may share some of these traits, many could be considered counter-productive in situations requiring teamwork and cooperation, two traits usually encouraged in engineering circles, and often advantageous in any group-related creative exercise!

Conscious Creativity:

Kemper³ (pp. 229-230) also offers a "Formula for Creativity" which consists of five steps. To paraphrase:

1. *Preparation*. Study and learn as much as possible in the subject area (and possible in general!)
2. *Concentration*: Try diligently to solve the problem in as many ways as possible.
3. *Incubation*. "Sleep on it" or let it percolate in your subconscious for a while. This break may provide an opportunity for conscious roadblocks to fade and subconscious creativity to break through.
4. *Inspiration*. Often, a solution (or an innovative idea) will suddenly "appear" after a period of "incubation"..

⁵ Taylor, C. W., and Barron, F., eds., 1963, *Scientific Creativity: Its recognition and Development*, Wiley, New York, pp. 385-386

5. *Verification.* Check to see if the new idea can be made to work. May require a persistent and determined approach.

The theory suggested here (and commonly supported) is that apparent “flashes” of inspiration are often the result of a significant amount of previous work.

Inhibitors to Creativity:

Roadblocks to creative solutions or ideas are common. Kemper³ describes three common problems that must be overcome (pp. 228-229).

The first, “persistence of a misleading set”, is the problem of being mentally ‘trapped’ by the first (or at least an early) solution, and being unable to get past this to generate more, and possibly better, alternatives.

The second is called “functional fixedness”. It is similar to the first in that one is mentally trapped by what already exists. The main difference is that it usually applies to accepted *uses* for objects or processes, and our inability to see them applied in significantly different ways or circumstances.

Finally, “premature criticism” can also stifle creativity in both individual and group situations. This is reflected in the rules cited for “brainstorming”, where criticism is strictly prohibited during the idea creation stage. The objective is to avoid the mental trap of thinking why something will not work and instead focusing on what might work.

The purpose of recognizing these inhibitors is that they might be eliminated or at least detected early enough to avoid their deleterious effects on the creative process.